R5

5N1

DEC ID 198850001.2

On-Refuge
entered OLDFWS

TECHNICAL ASSISTANCE REPORT

CONTAMINANTS IN FISH AND SEDIMENTS OF GREAT SWAMP NATIONAL WILDLIFE REFUGE, MORRIS COUNTY, NEW JERSEY

RESULTS OF 1988 SAMPLING EFFORTS

DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE

April 1991

<u>TECHNICAL ASSISTANCE REPORT</u>

CONTAMINANTS IN FISH AND SEDIMENTS OF GREAT SWAMP NATIONAL WILDLIFE REFUGE, MORRIS COUNTY, NEW JERSEY

RESULTS OF 1988 SAMPLING EFFORTS

Prepared for:

U.S. Fish and Wildlife Service
Refuges and Wildlife (Region 5)
Newton Corner, Massachusetts 02158

Prepared by:

U.S. Fish and Wildlife Service
Fish and Wildlife Enhancement
New Jersey Field Office
Pleasantville, New Jersey 08232

April 1991

Project Leader: Clifford G. Day

Assistant Project Leader: Michael T. Chezik

Preparer / Project Biologist: Tom Augspurger

PREFACE

Information presented in this report is final documentation of the 1988 environmental contaminants evaluation of fish and sediments in and adjacent to Great Swamp National Wildlife Refuge, Morris County, New Jersey. The report supplants a working draft of the same title and authorship released for peer review and comment in November 1989. This contaminants evaluation represents continuing cooperative monitoring of Great Swamp National Wildlife Refuge by the U.S. Fish and Wildlife Service's activities of Fish and Wildlife Enhancement, and Refuges and Wildlife in Region 5. Study design, implementation, data analyses, and reporting were completed by Environmental Contaminants personnel in the New Jersey Field Office (Fish and Wildlife Enhancement). Funding for the project was provided by Refuges and Wildlife.

Questions, comments, and suggestions related to this report are encouraged, and written inquiries should be directed to the Service at the following address:

U.S. Fish and Wildlife Service
New Jersey Field Office
927 North Main Street (Building D-1)
Pleasantville, New Jersey 08232

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

This monitoring effort was designed, coordinated and conducted by F. Timothy Prior, a former Environmental Contaminants Specialist in the New Jersey Field Office currently with the U.S. Army at Fort Devens, Massachusetts. Prior's meticulous record keeping greatly facilitated data analysis and report writing.

Sample collection was assisted by Robert Burr of the New Jersey Field Office and Daniel Sparks, now of the Fish and Wildlife Service's Bloomington, Indiana Field Office.

Analytical work was conducted by the Environmental Trace Substance Research Center of the University of Missouri, Mississippi State Chemical Laboratory, and the Soil Testing Lab of Cook College's Department of Soils and Crops, Rutgers University. The quality of their work is much appreciated.

CONVERSION FACTORS

1 HECTARE = 2.47 ACRES

1 KILOMETER = 0.62 MILE

1 METER = 39.37 INCHES

1 CENTIMETER = 0.3937 INCHES

INTRODUCTION

The Great Swamp National Wildlife Refuge (GSNWR), formally established in 1960, consists of approximately 2870 hectares of wetlands and uplands in Morris County, New Jersey (Figure 1). The refuge occupies about 20 percent of the Great Swamp watershed which covers portions of Morris and Somerset counties. Managed for wildlife resting, feeding, and breeding, and wildlife oriented education and recreation, GSNWR provides habitat for a diversity of fauna and flora (U.S. Fish and Wildlife Service, 1987), including the federally endangered bald eagle (*Haliaeetus leucocephalus*) and peregrine falcon (*Falco peregrinus*). State of New Jersey endangered or threatened species using GSNWR include osprey (*Pandion haliaetus*), great blue heron (*Ardea herodias*), yellow crowned night heron (*Nycticorax violacea*), barred owl (*Strix varia*), blue-spotted salamander (*Ambystoma laterale*), bog turtle (*Clemmys muhlenbergi*), and wood turtle (*Clemmys insculpta*). The refuge also supports a number of game species including white-tailed deer (*Odocoileus virginianus*), Eastern cottontail (*Sylvilagus floridanus*), Gray squirrel (*Sciurus carolinensis*), American woodcock (*Scolopax minor*), wild turkey (*Meleagris gallopavo*), Canada goose (*Branta canadensis*), wood duck (*Aix sponsa*), and mallard (*Anas platyrhynchos*). Juxtaposed with this wealth of biota are a number of pollutant sources located within and adjacent to GSNWR. These include two abandoned municipal solid waste landfills, a satellite site of a National Priorities List (Superfund) hazardous waste site (Asbestos Dump, Millington, New Jersey), and two municipal sewage treatment plants (Chatham Township and Morris Township) which discharge into refuge feeder streams (Figure 2). Urban and agricultural run-off are also of concern in this developing watershed located just 40 kilometers from New York City (U.S. Fish and Wildlife Service, 1984).

Several studies of GSNWR have indicated the potential for habitat degradation due to the presence of xenobiotics and elevated levels of naturally occurring compounds and elements. Rolling Knoll Landfill, also known as Green Village Disposal or Miele Landfill, underwent an environmental audit in 1985 which identified heightened concentrations of nine heavy metals, including lead and mercury, as well as the presence of a number of semi-volatile compounds, polychlorinated biphenyls (PCB), and pesticides (NUS Corporation, 1985 and 1986). This defunct sanitary landfill occupies approximately 55 hectares of wetlands and uplands of which about 12 hectares are located in the Wilderness Area of GSNWR. Impacts of the waste site on surrounding biotic and abiotic resources are largely undocumented.

A similar investigation of the 0.4 hectare Harding dump, used for the disposal of municipal trash from approximately 1959 to 1969, indicated the presence of low levels of polycyclic aromatic hydrocarbons (PAH) and asbestos fibers (NUS Corporation, 1987). These results were based on limited sampling of the site itself, and off-site impacts are unknown.

Water quality impacts from sewage treatment plants and urban run-off have also been documented in the watershed in the form of nutrient and chloride enrichment (Katz et al., 1986; Katz et al., 1987; Katz and Katz, 1984). The U.S. Environmental Protection Agency conducted a monitoring program to assess water quality in the Great Swamp watershed, but their approach focused on

FIGURE 1. GREAT SWAMP STUDY AREA

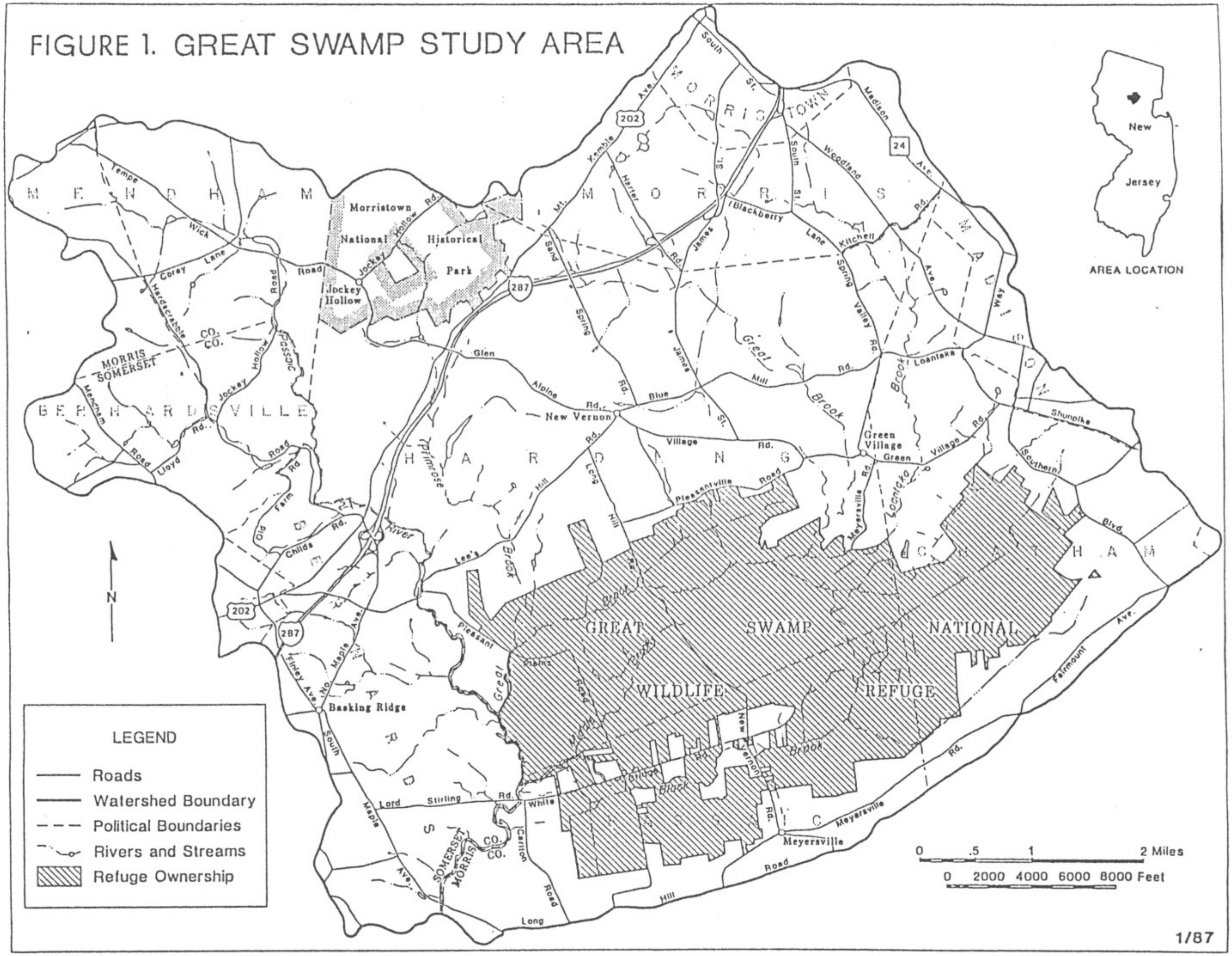
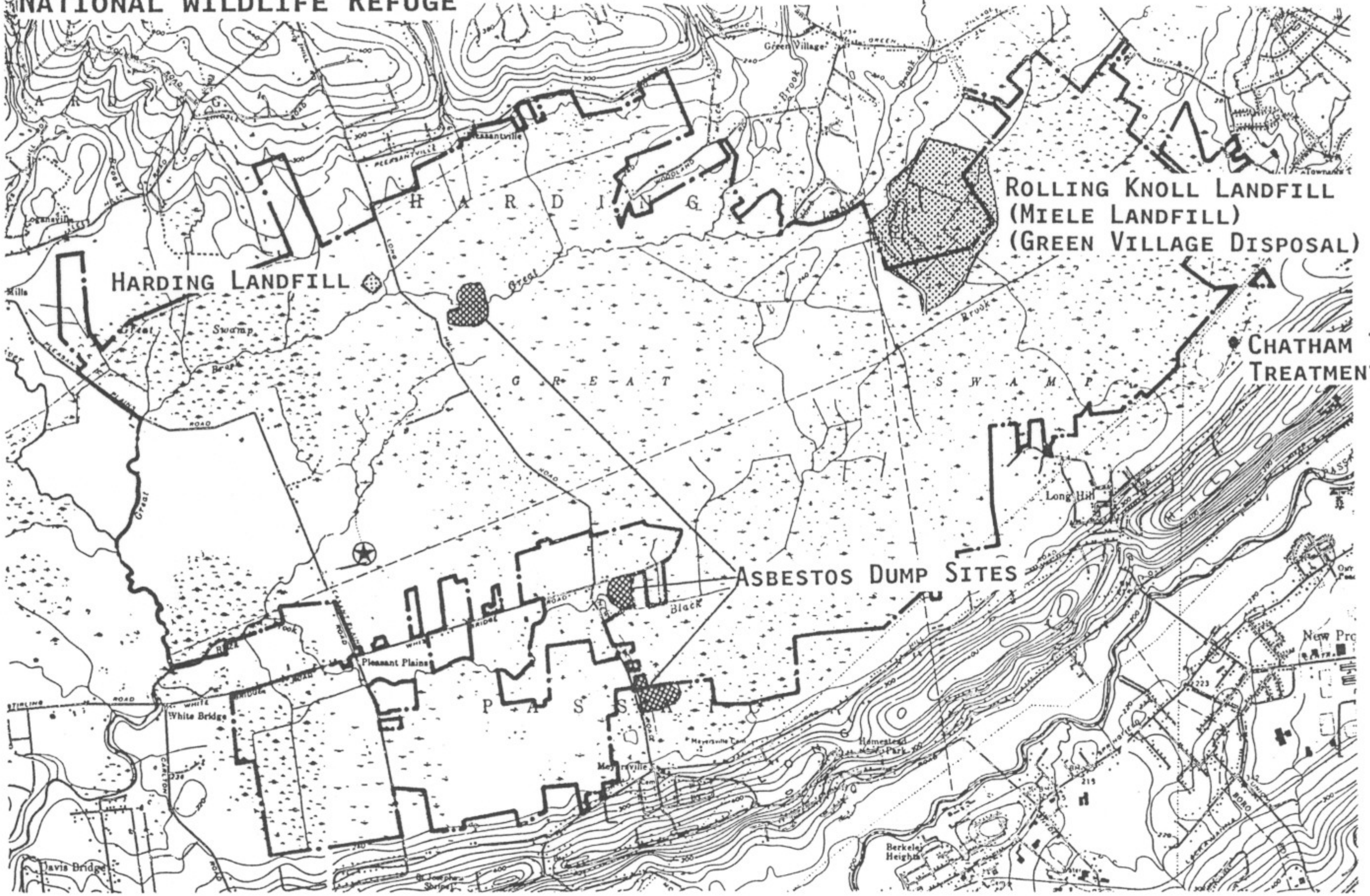


FIGURE 2. KNOWN OR SUSPECTED SOURCES OF CONTAMINANTS TO GREAT SWAMP NATIONAL WILDLIFE REFUGE



.5 0 .5 1 Mile

1000 0 2000 4000 6000 Feet

Contour Interval 20 Feet

NORTH

LEGEND

Refuge Headquarters

Refuge Ownership Boundary

conventional water quality parameters (e.g., ammonia, dissolved oxygen, total suspended solids) and did not include monitoring for elemental contaminants, PAHs, and other potentially toxic components of urban run-off and sewage treatment plant effluent (U.S. Environmental Protection Agency, 1988). Without further information in this regard, assessing long-term implications of point and non-point source pollutant loading of GSNWR would be impossible.

This study was designed to achieve three goals which would assist future refuge management and serve to focus further study:

1) identify toxic contaminants present in streams flowing into the refuge;

2) characterize ambient concentrations of elemental contaminants, organochlorines, and PAHs in GSNWR sediment and fish to serve as baseline data for future reference and planning; and,

3) identify elemental contaminant, organochlorine, and PAH contamination within GSNWR arising from the identified dumps, sewage treatment plants, and other potential contaminant sources (Long Hill Road, unidentified dumps, residential and business park development, and agriculture).

METHODS

SAMPLING SCHEME

Sample stations (Figure 3) were chosen using an intentionally biased approach to concentrate sampling around known or potential sources of contamination and along most of the water courses entering the refuge near their point of entry (see Appendix A for a narrative description of each sample site). Composite sediment samples were collected at these 39 stations in May and June of 1988 while fish were collected at 14 of the sites. The eastern mudminnow (*Umbra pygmaea*) was chosen as the target fish species for the study due to its abundance in the region and intimate association with area sediments. Composite samples of three to 29 mudminnows (enough to attain suitable sample size) were collected for all fishing stations except station 02. At this station, a composite sample of two brown bullheads (*Ictalurus nebulosus*) was collected for the organochlorine scan due to the unavailability of the target species. Totals for media sampled and analyses performed are as follows:

39 composite sediment samples for elemental contaminants analyses and total organic carbon and grain size determination;

23 composite sediment samples for organochlorine scans and PAH analyses; and,

14 composite fish samples for heavy metals and organochlorine analyses.

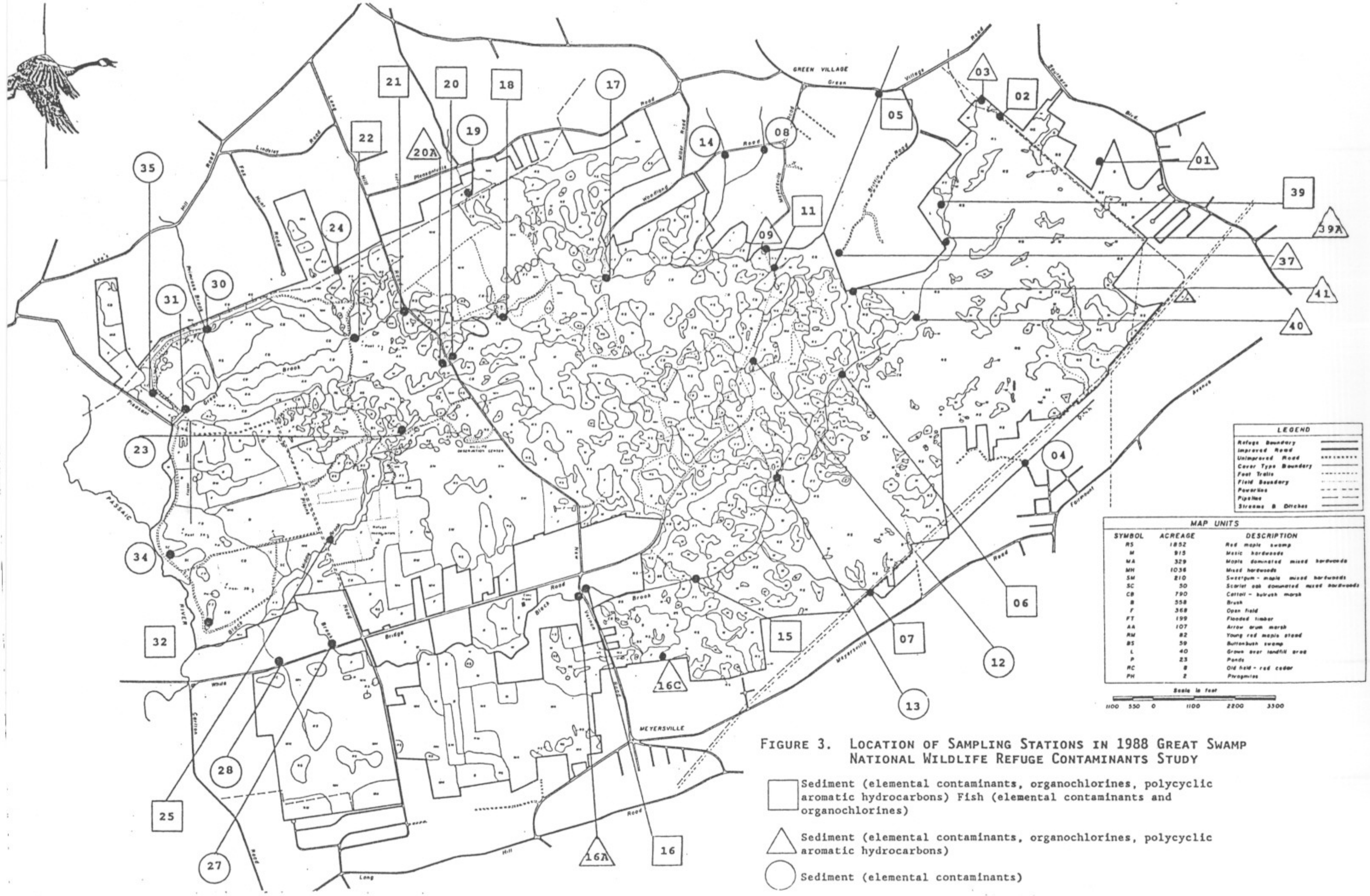


FIGURE 3. LOCATION OF SAMPLING STATIONS IN 1988 GREAT SWAMP NATIONAL WILDLIFE REFUGE CONTAMINANTS STUDY

□ Sediment (elemental contaminants, organochlorines, polycyclic aromatic hydrocarbons) Fish (elemental contaminants and organochlorines)

△ Sediment (elemental contaminants, organochlorines, polycyclic aromatic hydrocarbons)

○ Sediment (elemental contaminants)

SAMPLING METHODS

A 2.9 centimeter (outside diameter) soil probe with 2.5 centimeter stainless steel inserts (Arts Manufacturing and Supply, Inc.) was used to collect five sediment samples at each sample station working up-stream. The surficial eight centimeters of each core were composited and homogenized to form the sample for analysis. Samples were stored in acid and solvent rinsed glass containers with teflon cap liners procured from I-Chem Research. A decontamination procedure, consisting of an ambient water rinse, scrubbing, distilled water rinse, acetone rinse, air drying, and a second distilled water rinse, was completed for all sample equipment between sample stations.

Fish were collected with a gasoline powered Coffelt Electronics Company, Inc. backpack electro-shocker (Model BP-1C). Between 10 and 40 grams of whole fish composites were stored in containers identical to those used for sediment preservation.

All samples were immediately placed in coolers with dry ice. Upon returning from the field, the samples were stored in a conventional freezer until shipment (again with dry ice) to analytical laboratories.

ANALYTICAL METHODS

Inorganic analyses were performed at Environmental Trace Substances Research Center, University of Missouri. Sediment samples were analyzed via an inductively coupled plasma emission spectroscopy (ICP) scan for elemental contaminants. In addition, mercury content was determined by cold vapor reduction atomic absorption spectroscopy (CVA), and levels of silver, thallium, and cadmium were assessed by graphite furnace atomic absorption. Tissues were analyzed via an ICP scan and CVA determination of mercury.

Organic analyses were performed at Hand Chemical Laboratory, Mississippi State University. Organochlorine scans (see Appendix D for analytes) were performed by electron capture gas chromatography (GC), while PAH analyses were done by flame ionization GC and fluorescence high pressure liquid chromatography.

A portion of each sediment sample was sent to Cook College Department of Soils and Crops, Rutgers University, for organic matter determination by loss on ignition, and particle size distribution analyses by Bouyoucos cylinder. Detailed descriptions of all the analytical methodologies are provided in Appendix B along with sample preparation procedures (homogenization, extraction, clean-up, and digestion) and percent moisture and lipid determination procedures.

RESULTS

SEDIMENT

Table 1, Figure 4, and Table 2 present summary data and statistics for elemental contaminants, organochlorines, and PAHs respectively in GSNWR sediments. The information in Table 1 represents the range in values and the geometric mean for various subsets of GSNWR sediments.

Table 1. Summary of ambient concentrations of all elemental contaminants in various subsets of Great Swamp National Wildlife Refuge sediments (all values in ug/g dry weight)

	Ag	Al	As	B	Ba	Be	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Ni	Pb	Se	Sr	Tl	V	Zn
All Data Points																					
Minimum	<0.01	4910	<7	<2	42.7	0.10	0.07	9.1	9.8	5420	0.02	804	40	<1	7	8	<6	8.4	<0.1	14	28
Maximum	17	31400	10	16	690	2.4	14	140	1180	130000	7.5	7340	724	30	110	1320	<50	62.8	0.31	118	2500
Mean	0.51	14442	NA	NA	132	0.85	0.78	25	59	19407	0.32	2446	229	NA	17	72	NA	22.7	NA	39	143
Median	0.05	13100	NA	NA	121	0.76	0.38	21	29	14400	0.11	2010	198	NA	14	33	NA	17.8	NA	36	72
Culled Data*																					
Minimum	<0.01	4910	<10	<2	42.7	0.1	0.07	9.1	9.8	5420	0.02	804	40	<2	7	8	<6	8.4	<0.1	14	28
Maximum	0.29	31400	10	11	220	1.8	1.3	43	56.0	39300	0.30	7340	624	<2	28	92	<20	62.8	0.31	118	175
Mean	0.06	14618	NA	NA	115	0.8	0.37	23	28	16603	0.11	2644	235	NA	15	34	NA	21.6	NA	40	72
Median	0.05	13100	NA	NA	109	0.8	0.28	22	25	13700	0.10	2105	208	NA	14	31	NA	15.9	NA	35	67
Entering GSNWR^																					
Minimum	0.02	4910	<8	<2	42.7	0.33	0.10	11	9.8	7790	0.02	1270	43	<2	7	8	<8	9.8	<0.1	21	42
Maximum	0.29	25200	<20	9.9	213	1.6	1.3	43	53	39300	0.30	3870	594	<4	23	92	<20	62.8	0.2	118	175
Mean	0.09	13620	NA	NA	119	0.85	0.48	22	32	16058	0.13	2166	242	NA	14	32	NA	29.3	NA	47	81
Median	0.05	11400	NA	NA	114	0.76	0.57	21	30	11500	0.11	1930	210	NA	13	23	NA	19.5	NA	37	78
Interior GSNWR (and culled)#																					
Minimum	<0.01	5740	<10	<2	50.1	0.10	0.07	9.1	10	5420	0.04	804	40	<1	7	10	<9	8.4	<0.1	14	28
Maximum	0.10	31400	10	11	220	1.8	0.69	35	56	32600	0.30	7340	624	<3	28	69	<20	62.8	0.31	79	130
Mean	0.05	15041	NA	NA	110	0.80	0.29	23	27	16389	0.11	2830	212	NA	15	35	NA	18.4	NA	34	67
Median	0.05	14800	NA	NA	103	0.79	0.24	21	21	14300	0.10	2300	169	NA	14	38	NA	14.3	NA	31	62

NA = Statistic not applicable due to numerous no detects (<)
* Culled data omits known potential sources of contamination (Stations 4, 20, 20A, 21, 37, 39, 39A, 40, and 41 are omitted)
^ Data set comprised of those stations located on refuge feeder streams (Stations 1,2,3,4,5,7,8,9,14,19,24, and 30 are represented)
# Data omits known potential sources of contamination and stations lccated on feeder streams (Stations 6, 11, 12, 13, 15, 16, 16A, 16C, 17, 18, 22, 23, 25, 27, 28, 31, 32, 34, and 35 are represented)

Figure 4. Summary of Organochlorine Residues in Great Swamp National Wildlife Refuge Sediments
(all values ug/g dry weight)
(data provided only for those stations where compounds were detected)

Sample ID #	39
Compound	
g-Chlordane	0.02
a-Chlordane	0.02
p, p'-DDE	0.03
p, p'-DDD	0.07

Sample ID #	39A
Compound	
g-Chlordane	0.22
t-Nonachlor	0.09
PCB's (total)	1.70
a-Chlordane	0.19
p, p'-DDE	0.17
o, p'-DDT	0.34
p, p'-DDD	0.34
p, p'-DDT	0.22

Sample ID #	40
Compound	
p, p'-DDE	0.02
p, p'-DDD	0.04

Sample ID #	07
Compound	
p, p'-DDT	0.52

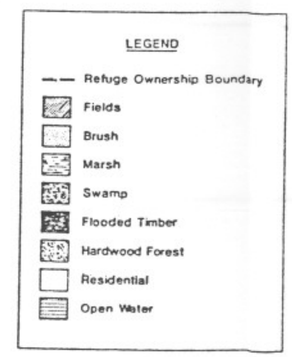


Table 2. Polycyclic aromatic hydrocarbons in Great Swamp sediments - summary statistics and selected station values (all values reported as ug/g dry weight)

COMPOUND	Minimum	Median	Maximum	05	07	16A	20	20A	21	39A
napthalene	ND	ND	0.17	ND	ND	0.04	0.15	0.07	ND	0.17
fluorene	ND	ND	0.86	0.05	0.06	0.15	0.86	0.29	0.31	0.02
phenanthrene	ND	0.05	5.98	0.39	0.41	1.19	5.98	2.36	2.79	0.19
anthracene	ND	ND	0.48	0.05	ND	0.13	0.48	0.18	0.26	0.07
fluoranthrene	0.01	0.10	2.33	0.39	0.93	0.62	2.33	1.99	2.13	0.19
pyrene	ND	0.15	4.49	0.37	0.64	0.82	4.49	2.17	2.62	0.19
1,2-benzanthracene	ND	0.03	1.41	0.19	0.12	0.20	1.41	0.67	0.38	ND
chrysene	ND	0.08	2.49	0.18	0.17	0.31	2.49	0.62	0.87	ND
benzo(b)fluoranthrene	0.01	0.06	1.21	0.14	0.17	0.31	0.80	1.21	0.79	0.63
benzo(k)fluoranthrene	ND	ND	0.24	0.01	0.06	0.04	0.20	0.13	0.16	0.24
benzo(e)pyrene	ND	0.10	1.99	0.22	0.12	0.69	1.99	1.09	0.80	1.15
benzo(a)pyrene	ND	0.05	2.17	0.31	0.17	0.53	1.36	2.17	0.97	1.37
1,2,5,6-dibenzanthracene	ND	0.02	0.31	0.05	ND	0.31	0.20	0.27	0.13	0.14
benzo(g,h,i)perylene	ND	0.06	1.43	0.22	0.06	0.69	1.00	1.43	1.07	0.17
Total PAHs				3	3	6	24	15	13	5

ND = None detected (<0.01 ppm)

FISH

Tables 3 and 4 summarize data for heavy metal and organochlorine residues in GSNWR fish. Table 3 provides National Contaminants Biomonitoring Program Data (Schmitt et al., 1990) for comparison of GSNWR values to those collected from a nationwide network of sampling locations, including the Delaware River (Station number 4, Trenton, New Jersey).

Table 3. Summary of Organochlorine Residues Found in Great Swamp National Wildlife Refuge Fish and Compared to 1984 National Contaminants Biomonitoring Program Data (All values ug/g wet weight unless otherwise noted) (Data reported only for those analytes which exceeded detection limits)

Compound	p,p-DDD	p,p-DDE	g-chlordane	a-chlordane	t-nonachlor	Dieldrin	Hept. Epox.
NCBP Geometric Mean	0.06	0.19	0.02	0.03	0.03	0.04	0.01
NCBP Maximum	2.55	4.74	0.35	0.66	1.00	1.39	0.29
NCBP Station 4	0.21	0.61	0.02	0.04	0.08	0.02	0.01
Stations w/cmpd.(%)	50	71	21	36	36	21	14
GSNWR Geometric Mean	0.02	0.02	0.01	0.02	0.01	0.01	0.01
GSNWR Maximum	0.03	0.03	0.01	0.03	0.02	0.02	0.01
Lower level of detection = 0.01 ppm except PCBs and toxaphene (0.05 ppm)							

Table 4. Geometric Mean and Selected Heavy Metal Levels for Great Swamp National Wildlife Refuge Fish (all data ug/g wet weight)

ELEMENT	Al	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
GSNWR Geometric Mean	10	0.05	0.47	1.6	53	0.08	7.4	0.26	0.18	72
Station 02	18	0.07	0.64	2.5	80		12.9			91
Station 05	38	0.16		2.2	82	0.11	8.1			92
Station 07				1.8		0.14		0.34	0.43	81
Station 11	16			2.8			9.9			93
Station 16				2.0		0.16		0.37		86
Station 18	20		0.55				12.0			
Station 21		0.07	0.48			0.11	9.0	0.41	0.46	86
Station 32					70				0.16	
Station 39			0.51		117			0.32		
See Appendix D for all analytical data										

As a first approximation of any contamination of the sediments tested, constituent concentrations were compared to National Oceanic and Atmospheric Administration (NOAA) environmental effects values (Table 5). The NOAA uses environmental effects values to assess potential biological effects of contaminated sediments as part of their national monitoring program. The NOAA defines ER-M values as the concentration above which biological effects were frequently or always observed or predicted among most species and the ER-L as the low end of the range of concentrations above which adverse effects may begin or are predicted among sensitive species (Long and Morgan, 1990). Although derived primarily from a database of marine systems, some freshwater toxicity information was used in the development of the environmental effects values. Because biological effects are expected to be more significant at a given level of contamination in freshwater versus marine environments, this approach will be somewhat less conservative than reliance on a database solely composed of freshwater toxicity information.

Table 5. Contaminant Concentrations in the Great Swamp National Wildlife Refuge Exceeding NOAA ER-L or ER-M Values (mg / kg dry weight)

Parameter	Ag	Cd	Cr	Cu	Hg	Ni	Pb	Zn	PAHs	PCBs	Total DDT
NOAA ER-M	2.2	9	145	390	1.3	50	110	270	35	0.40	0.350
NOAA ER-L	1	5	80	70	0.15	30	35	120	4	0.05	0.003
S 03					0.19						
T 07					0.22						0.52
A 11							38				
T 12					0.21		69				
I 14							59				
O 16A							44		6		
N 16C					0.30		42				
17							41				
N 18							38				
U 19							92	175			
M 20							38		24		
B 20A									15		
E 21					0.17		59	142	13		
R 24							46				
27							51				
28							57	130			
31							51				
32							40				
37					0.27						
39					0.20		47				0.10
39A	17	14	140	1180	8	110	1320	2500	5	1.7	1.07
40					0.26		39				0.06
41					0.42		210	325			

Raw data for elemental contaminants and synthetic organic residues in sediment were manipulated in an attempt to account and adjust for normal environmental heterogeneity so that man-induced perturbations of the system could be identified. Data for organochlorines and PAHs in GSNWR sediments were normalized to account for the percentage of organic carbon in the individual samples. A number of studies have illustrated the connection between the organic carbon content of sediments and their capacity to adsorb non-ionic organic compounds (Anderson et al., 1987; Rodgers et al., 1987).

Considering the variability of organic matter content in GSNWR sediments (Vecchioli et al., 1962), it is informative to normalize sediment data by dividing the sediment borne contaminant concentration by the sediment's fraction of organic carbon. Normalized data can be found in Appendix E, and our review of the normalized data revealed that DDT levels at GSNWR stations 07 (3.4 ug / g organic carbon) and 39A (2.1 ug / g organic carbon) exceed the U.S. Environmental Protection Agency's interim sediment quality criteria of 0.828 ppm, also expressed in terms of organic carbon (Chapman, 1989; U. S. Environmental Protection Agency, 1989b).

Sediment trace metal data were analyzed via a concentration ratio approach in addition to comparing concentrations directly. This ratio technique, described in White and Tittlebaum (1984) and Smith et al. (1987), is used to reduce the effects of variable sediment composition (organic matter content, particle size distribution, etc.) on sediment trace metal concentrations (Horowitz, 1985; Di Toro et al., 1989).

Whereas trace metals are naturally present in low concentrations which can be easily enhanced by anthropogenic activities, the levels of "conservative" elements (defined as metals of low environmental variability which are unlikely to be elevated in sediments from human activities) are naturally high by comparison (White and Tittlebaum, 1984). Even if anthropogenically elevated, conservative elements are less sensitive to change owing to their high sediment concentrations. A ratio of a sediment's trace metal content to its level of a conservative metal can hence compensate for differences in trace element concentration between two locations that may be due solely to environmental heterogeneity. By accounting for environmental variation, human-induced alterations are more easily assessed. The conservative metals chosen for this study are Fe and Al, not because of any classical definition of conservative elements, but because their concentrations in sediments are high relative to the trace metals of interest (Smith et al., 1987). The trace metal to Al and Fe ratios are offered in Appendix E, and the ratios for stations on and adjacent to the Rolling Knoll Landfill (Table 6) were analyzed via a statistical procedure described below.

The Wilcoxon rank sum test (Gilbert, 1987) was used to determine whether or not a significant difference existed between the concentration of contaminants immediately adjacent to Rolling Knoll Landfill and the corresponding pollutant concentrations up-gradient of the site. This non-parametric test, a variant of which is the Mann-Whitney test, was chosen primarily because it does not require the data to be normally distributed and is hence of value in application to environmental monitoring data which is often skewed to the

Table 6. Ratios of trace metal concentration (mg/kg) to Fe and Al (mg/g) for Great Swamp sediments around the Rolling Knoll Landfill

	Up-Gradient of Dump				Adjacent to Dump				
Station #	01	02	03	05	37	39	39A	40	41
Element									
Al	9	23	25	5	29	10	14	13	13
Fe	8	11	10	11	14	30	130	12	16
Ag	0.041	0.02	0.02	0.048	0.034	0.2	17	0.26	0.092
Ag / Al	0.005	0.001	0.001	0.010	0.001	0.020	1.214	0.020	0.007
Ag / Fe	0.005	0.002	0.002	0.004	0.002	0.007	0.131	0.022	0.006
Cd	0.16	0.68	0.72	0.1	0.91	1.2	14	0.88	1.2
Cd / Al	0.0	0.0	0.0	0.0	0.0	0.1	1.0	0.1	0.1
Cd / Fe	0.0	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.1
Cr	15	26	28	11	44	15	140	20	19
Cr / Al	1.7	1.1	1.1	2.2	1.5	1.5	10.0	1.5	1.5
Cr / Fe	1.9	2.4	2.8	1.0	3.1	0.5	1.1	1.7	1.2
Cu	15	38.1	40.5	9.8	58.9	18	1180	38.6	52
Cu / Al	1.7	1.7	1.6	2.0	2.0	1.8	84.3	3.0	4.0
Cu / Fe	1.9	3.5	4.1	0.9	4.2	0.6	9.1	3.2	3.3
Hg	0.087	0.13	0.19	0.051	0.27	0.2	7.5	0.26	0.42
Hg / Al	0.010	0.006	0.008	0.010	0.009	0.020	0.536	0.020	0.032
Hg / Fe	0.011	0.012	0.019	0.005	0.019	0.007	0.058	0.022	0.026
Ni	8	18	18	7	18	9	110	14	16
Ni / Al	0.9	0.8	0.7	1.4	0.6	0.9	7.9	1.1	1.2
Ni / Fe	1.0	1.6	1.8	0.6	1.3	0.3	0.8	1.2	1.0
Pb	17	18	18	8	31	47	1320	39	210
Pb / Al	1.9	0.8	0.7	1.6	1.1	4.7	94.3	3.0	16.2
Pb / Fe	2.1	1.6	1.8	0.7	2.2	1.6	10.2	3.3	13.1
Zn	41.5	79.0	76.2	48.1	68.0	106	2500	98.9	325
Zn / Al	4.6	3.4	3.0	9.6	2.3	10.6	178.6	7.6	25.0
Zn / Fe	5.2	7.2	7.6	4.4	4.9	3.5	19.2	8.2	20.3

right (Fowler, 1980; Gilbert, 1987; U.S. Environmental Protection Agency, 1989a). A good qualitative description of the test procedure and foundation is offered by Slauson (1988):

> The test statistic is computed from the ranks of the observations rather than the observed values. The ranks are determined by pooling the data and ranking the combined sample. If the groups come from the same population, then a ranking that puts all one group ahead of the other group is highly unlikely.

The test null hypothesis is Ho: The samples taken above and adjacent to the landfill come from the same population and contaminant concentrations at these locations are identical except for chance differences, versus the alternative hypothesis, Ha: The contaminant concentrations on and adjacent to the landfill consistently exceed those up-gradient of the landfill. More information about the applicability of this procedure can be found in most nonparametric statistical methods texts (Hollander and Wolfe, 1973). Results of this statistical procedure as applied in assessing the impacts of Rolling Knoll Landfill are discussed below.

DISCUSSION

SEDIMENT

Ambient concentrations of trace metals in GSNWR sediments were significantly affected by the presence of known contaminant sources as indicated in Table 1. Geometric mean heavy metal concentrations have only slight variation between the arbitrary divisions of sampling stations (all data, data from stations on refuge feeder streams, all data minus known or suspected contaminant sources, and all data minus stations on feeder streams and adjacent to contaminant sources) while traditional mean values for the entire data set are skewed toward high concentrations, largely due to the influence of station 39A. An exception to this observation is apparent where stream sediments taken above GSNWR appear elevated in Cd when compared to stations internal to GSNWR. Elevated levels of Cd in feeder stream sediments may be caused by road run-off because samples were taken adjacent to roadways in these areas (a potential confounding effect which inhibits our use of the data for statistical analysis of the observed trend).

Comparison of sediment data to background levels of elemental contaminants in New Jersey soils reveals that only sites 19 (Cd and Zn), 21 (Zn), 28 (Zn), 39A (Ag, Ba, Cd, Cu, Cr, Fe, Hg, Pb, Ni, and Zn), and 41 (Pb and Zn) significantly exceed expected values (Motto, 1989). This is also apparent in Table 5. Although the NOAA environmental effects levels for Hg and Pb are also often exceeded as depicted in Table 5, these parameters are not outside the range for New Jersey soils except as indicated above (Motto, 1989).

Our data (Table 6) indicate levels of Cd, Cu, Hg, and Pb are significantly (a = 0.05) elevated in the sediments around the periphery of Rolling Knoll Landfill when compared to up-gradient sediment samples (a = 0.05 equates to a 95 % confidence coefficient; i.e., 95 % confident in the results of the hypothesis test). Additionally, there is evidence for localized elevation of Ag, Ba, Cr, Fe, Ni, and Zn at station 39A located on refuge property at the south east toe of the landfill. The U.S. Environmental Protection Agency investigation of Rolling Knoll Landfill also indicated above background concentrations of Ba, Cu, Pb, Hg, and Zn, as well as Al, K, Na, and a number of semivolatile compounds (NUS Corporation, 1985 and 1986).

Sediment residues of p,p-DDD, p,p-DDE, and chlordane components were also elevated around Rolling Knoll Landfill with p,p-DDD and p,p-DDE statistically elevated (Wicoxon rank sum test, a = 0.05). PCBs were locally elevated at station 39A (Figure 4). Station 07 was the only location not associated with Rolling Knoll Landfill to contain organochlorines above the method detection limits; 0.52 ppm (dry weight) p,p-DDT was detected at this location, but was absent in up-gradient and down-gradient samples. It is possible that areas of greater DDT enrichment than that detected in this initial screening exist around station 07. Further sampling would be required to determine the significance of this observation.

PAHs in sediment at the 23 stations sampled ranged from 0.08 to 24 ppm (dry weight) with a median concentration of 0.70 ppm. These data (Table 2) revealed two lines of evidence indicating the potential for environmental degradation from the Dietzman Tract and heavily travelled roads: 1) carbon normalized sediment data demonstrate that sediment heterogeneity alone can not explain elevated PAHs at these locations; and 2) if atmospheric deposition or refuge feeder streams were the primary sources of these compounds, a more even distribution of these products of incomplete combustion would be expected. Statistical comparison of the up-gradient and ambient contaminant concentrations around the Harding Dump and Dietzman Tract was inhibited due to the limited number of samples taken up-stream of these locations. PAHs, including the carcinogenic compounds fluorene, pyrene, 1,2-benzanthracene, chrysene, and benzo(a)pyrene, recorded at stations 20, 20A and 21 may cause sublethal stress in benthic organisms at current levels (Eisler, 1987b; Long and Morgan, 1990); the extent of this contamination in Great Brook and Middle Brook adjacent to Long Hill Road requires further delineation.

The GSNWR has a very favorable hydrologic regime for the minimization of contaminant transport. Relatively impermeable silt and clay beds confine the deep ground water of the Great Swamp watershed which exhibits artesian behavior leading to ground water discharge in the swamp (Miller, 1965). Contamination of the confined aquifer is unlikely throughout most of the GSNWR due to this upwelling of ground water (i.e., contaminants will not move against the artesian head) and the presence of clay confining beds (which are effectively impermeable barriers). An NUS Corporation (1986) borehole investigation of Rolling Knoll Landfill confirmed the base of the fill to be a firm clay and silt layer, approximately 18 to 38 meters in thickness, underlying organic peat and silt.

Contaminant migration via the water table aquifer and surface water is impeded by the relatively flat hydraulic gradient and low permeability of surficial materials which results in low ground water velocity and water ponding (Vecchioli et al., 1962; Miller, 1965). When coupled with the pollutant retention capacity of highly organic soils, significant surface or shallow subsurface mobilization of contaminants is not expected. The exceptions to these generalized findings would occur in areas where there are breaches in the clay lenses.

A U.S. Geological Survey geophysical reconnaissance survey of the Rolling Knoll Landfill has indicated the presence of such breaches in the predominate clay substrate in the form of sand and gravel deposits on the south and east side of the landfill. The same U.S. Geological Survey work documented sharply elevated specific conductivity of the surface water on the east side of the landfill, suggesting emanating leachate (Hardy, pers. comm., 1989). It appears these sand and gravel areas are acting as conduits for landfill leachate to exit the landfill. The results of previous investigations support those found in this study with regard to elevated inorganics on and adjacent to Rolling Knoll Landfill.

FISH

Although ambient concentrations of trace metals in GSNWR fish exceed 1984 National Contaminants Biomonitoring Program averages for Cd (0.03 ppm), Cu (0.65 ppm), Pb (0.11 ppm), and Zn (21.7 ppm), Schmitt and Brumbaugh (1990) report that Cu and Zn appear to be regulated by fish and that environmental enrichment of these metals is not reflected in fish tissue.

Elevations of Cd (station 05) and Pb (stations 07 and 21) identified in Table 4 may reflect localized enrichment by road run-off rather than a stream-wide enrichment. This supposition is supported by the absence of elevated levels at other stations along the same stream courses; re-sampling these areas along transects from roadways would aid in discerning the extent of these localized elevations. Fe at station 39 is also locally elevated; this is likely an indication of bioaccumulation of Fe in leachate from Rolling Knoll Landfill.

Hg levels in the fish collected may be cause sublethal reproductive impairment in avian predators (Eisler, 1987a). This appears to be a watershed-wide phenomenon, and current GSNWR levels are lower than other values obtained in the region (Jacangelo, 1977).

Organochlorine residues in the fish sampled indicate some accumulation of synthetic organic insecticides, primarily chlordane components and DDT degradation products. All of these compounds were detected in low levels, and do not appear to represent toxic hazards to aquatic biota. A qualitative plot of the organochlorine residue data on a refuge map indicates that levels in biota are slightly higher in stations to the northeast (02, 05, and 11) than those to the southwest, reflecting greater input to the refuge from feeder streams than other sources (e.g., atmospheric). A similar trend was apparent in limited sampling of Great Brook fishes in 1981 (U.S. Fish and Wildlife Service, unpublished data). Total DDT (parent compound plus metabolites and degradation products) averaged 0.17 ppm and total chlordane averaged 0.10 ppm at the confluence of Loantaka Brook, while total DDT averaged 0.03 ppm and total chlordane was below a 0.01 ppm detection limit near the Pleasant Plains Road crossing.

Some interesting inferences can be made with respect to the DDT residue data. The presence of only p,p-DDD and p,p-DDE in tissues without the parent compound p,p-DDT suggests continued weathering and degradation of historic DDT inputs rather than continued exposure to the parent compound (Schmitt et al., 1990). This also applies to the ratio of DDT and degradation products in GSNWR sediments (Blus et al., 1987). If this hypothesis is correct, future residue analyses should also show a decline in the levels of the degradation products.

CONCLUSIONS/RECOMMENDATIONS

1) Contaminant concentrations in sediments on and adjacent to Rolling Knoll Landfill exceed up-gradient concentrations and may pose a threat to local fauna and flora.

   a) Investigation of heavy metal accumulation by local biota should be continued.

   b) Contracted efforts by U.S. Geological Survey to characterize ground water contamination should be continued.

2) PAHs and DDT metabolites at several stations exceed sediment screening criteria for biological effects.

   a) Further sampling around the Dietzman Tract (Asbestos Dump satellite site) will aid in assessing the origin and extent of elevated PAHs at this location.

3) Concentrations of contaminants in sediment and fish from most other areas of the refuge are of marginal concern.

   a) Cd may be elevated in feeder stream sediments; this element should be a focus of future studies (discern sources and assess trends).

   b) Pb appears elevated in mudminnows at stations 07 and 21; this element should be a focus of future studies (re-sampling along transects would aid in discerning the origin and extent of localized elevations).

   c) A follow-up study of the contaminants targeted in this investigation should be completed in five to ten years to discern possible changes in sediment and fish tissue quality.

LITERATURE CITED

Anderson, J., W. Birge, J. Gentile, J. Lake, J. Rodgers, Jr., and R. Swartz. 1987. Biological effects, bioaccumulation, and ecotoxicology of sediment associated chemicals. In K.L. Dickson, A. W. Maki, and W. A. Brungs, eds., Fate and Effects of Sediment-Bound Chemicals in Aquatic Systems. Pergamon Press, Toronto.

Blus, L. J., C. J. Henny, C. J. Stafford, and R. A. Grove. 1987. Persistence of ddt and metabolites in wildlife from Washington State orchards. Arch. Environ. Contam. Toxicol. 16: 467-476.

Chapman, P. M. 1989. Current approaches to developing sediment quality criteria. Environ. Toxicol. Chem. 8: 589-599.

Di Toro, D. M., J. D. Mahony, D. J. Hansen, K. J. Scott, M. B. Hicks, S. M. Mayr, and M. S. Redmond. 1989. Toxicity of cadmium in sediments: the role of acid volatile sulfide. Unpublished draft. Manhattan College, The Bronx.

Eisler, R. 1987(a). Mercury hazards to fish, wildlife, and invertebrates: a synoptic review. U. S. Fish Wildl. Serv. Biol. Rep. 85(1.10).

Eisler, R. 1987(b). Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a synoptic review. U. S. Fish Wildl. Serv. Biol. Rep. 85(1.11).

Fowler, G. W. 1980. Nonparametric statistical procedures for comparing two populations. Res. Invent. Notes. BLM-27. U.S. Depart. Interior, Bur. Land Manag., Denver.

Gilbert, R. O. 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold Company, New York.

Hollander, M. and D. A. Wolfe. 1973. Nonparametric Statistical Methods. Wiley, New York.

Horowitz, A. J. 1985. A Primer on Trace Metal-Sediment Chemistry. U. S. Geolog. Survey Water Supply Paper 2277. Alexandria, VA.

Jacangelo, D. J. 1977. Mercury in freshwater fish. State of New Jersey Depart. Environ. Protect., Div. Fish, Game and Shellfisheries, Trenton, NJ.

Katz, A. H., H. M. Katz and L. M. Gonzalez. 1987. Quantification of tributary effect on pollution abatement. Annals of the New York Acad. Sci. 494: 430-431.

Katz, H. M. and A. H. Katz. 1984. Great Swamp- a threatened freshwater wetland. Annals of the New York Acad. Sci. 435: 292-295.

Katz, H. M., A. H. Katz and E. Samanns. 1986. Sediment accumulation and dynamics in an urbanizing area. Annals of the New York Acad. Sci. 463: 186-189.

Long, E. R. and L. G. Morgan. 1990. The potential for biological effects of sediment-sorbed contaminants tested in the national status and trends program. Nat. Ocean. Atm. Admin., Seattle. NOAA Tech. Mem. NOS OMA 52.

Miller, E. G. 1965. Effect of Great Swamp, New Jersey, on streamflow during base-flow periods. U. S. Geolog. Survey Prof. Paper 525-B: B177-B179.

Motto, H. L. 1989. Metal values in surface soils in New Jersey. Unpublished data. Rutgers University, New Brunswick, NJ.

NUS Corporation. 1985. Final draft site inspection report and hazardous ranking system model, Green Village Disposal: Report number 02-8301-55A-SI-RI. NUS Corporation, Edison, NJ.

NUS Corporation. 1986. Letter from Diane Trube, NUS Corporation, to Diana Messina, U.S. Environmental Protection Agency, describing results of borehole investigation of Green Village Disposal. C-584-10-86-41. NUS Corporation, Edison, NJ.

NUS Corporation. 1987. Draft site inspection report, Harding dump, Harding Township, New Jersey. EPA work assignment number 94-2JQ7. NUS Corporation, Edison, NJ.

Rodgers, J. H. Jr., K. L. Dickson, F. Y. Saleh, and C. A. Staples. 1987. Bioavailability of sediment-bound chemicals to aquatic organisms - some theory, evidence and research needs. In K.L. Dickson, A. W. Maki, ans W. A. Brungs, eds., Fate and Effects of Sediment-Bound Chemicals in Aquatic Systems. Pergamon Press, Toronto.

Schmitt, C. J., and W. C. Brumbaugh. 1990. National contaminants biomonitoring program: concentration of arsenic, cadmium, copper, lead, mercury, selenium, and zinc in U.S. freshwater fish, 1976-1984. Arch. Environ. Contam. Toxicol. 19: 731-747.

Schmitt, C. J., J. L. Zajicek, and P. H. Peterman. 1990. National contaminants biomonitoring program: residues of organochlorine chemicals in U.S. freshwater fish. Arch. Environ. Contam. Toxicol. 19: 748-781.

Slauson, W. L. 1988. Graphical and statistical procedures for comparing habitat suitability data. U.S. Fish Wildl. Serv. Biol. Rep. 89(6).

Smith, J. A., P. T. Harte and M. A. Hardy. 1987. Trace-metal and organochlorine residues in sediments of the Upper Rockaway River, New Jersey. Bull. Environ. Contam. Toxicol. 39: 465-473.

U.S. Environmental Protection Agency. 1988. Great Swamp Water Quality Monitoring Study Data Report. New York.

U.S. Environmental Protection Agency. 1989a. Ecological Assessment of Hazardous Waste Sites. EPA 600/3-889/013. Corvallis, Oregon.

U. S. Environmental Protection Agency. 1989b. Briefing report to the EPA science advisory board on the equilibrium partitioning approach to generating sediment quality criteria. EPA 440/5-89-002. Office of Water Regulation And Standards, Washington, D.C.

U.S. Fish and Wildlife Service. 1984. Great Swamp National Wildlife Refuge Hydrology Study. Basking Ridge, NJ.

U.S. Fish and Wildlife Service. 1987. Final Environmental Impact Statement on the Master Plan for the Great Swamp National Wildlife Refuge, Morris County, New Jersey. Newton Corner, MA.

Vecchioli, J., H. E. Gill and S. M. Lang. 1962. Hydrologic role of the Great Swamp and other marshland in Upper Passaic River Basin. J. Amer. Water Works Assoc. 54: 695-701.

White, K. D. and M. E. Tittlebaum. 1984. Statistical comparison of heavy metal concentrations in various Louisiana sediments. Environ. Monitor. Assess. 4: 163-170.

PERSONAL COMMUNICATION

Hardy, M. A. 1989. October 11 meeting at the U.S. Geological Survey, Water Resources Division office in Trenton, New Jersey.

APPENDICES

APPENDIX A

NARRATIVE OF SAMPLING LOCATIONS

Following is a narrative description of each sampling location for the 1988 investigation of contaminants in fish and sediments of Great Swamp National Wildlife Refuge, Morris County, New Jersey. Station numbers correspond to those in Figure 3 of the main text. In addition to these descriptions, the U.S. Fish and Wildlife Service's New Jersey Field Office maintains a photographic record of each station and the data sheets used to document sample collections (which provide directions to collection locations).

STATION	NARRATIVE
01	Un-named brook entering mesic area between northeast refuge boundary and pond at Noe Pond Pool Club. Down-gradient of Southern Boulevard (Chatham Township) and the Fairmont Golf Course.
02	Headwaters of Black Brook inside northeast corner of refuge and opposite Green Village Post Office. Sample taken north of impoundment along power line easement.
03	Headwaters of Black Brook inside northeast corner of refuge and opposite Green Village Post Office. Sample taken in stream crossing under power line easement (northwest of station 02).
04	Chatham Township sewage treatment plant ditch (tributary of Black Brook) downstream of unpaved extension of Long Hill Avenue (off Fairmont Avenue).
05	Loantaka Brook at Green Village Road crossing. Sample taken south (down-stream) of road.
06	Black Brook within Wilderness Area of refuge near end of Yellow Trail.
07	Chatham Township sewage treatment plant ditch where it crosses power line right-of-way and enters refuge (up-stream of junction with Black Brook).
08	Easterly fork of un-named brook south of its crossing at Woodland Road (site of USEPA water quality sample).
09	Loantaka Brook at Meyersville Road crossing. Sample taken down-stream of bridge, entrance point to refuge Wilderness Area.
11	First stream crossing on trail from Meyersville Road parking lot to refuge Wilderness Area. Sample taken east (up-stream) of bridge.
12	Old Meyersville Road Trail at second stream crossing (south of Meyersville Road parking lot). Sample taken up-stream of bridge.
13	Black Brook east of the end of Blue Trail where brook pinches between two mesic headlands.
14	Un-named creek crossing at Woodland Road (less than 100 yards west of station 08). Sample taken south (down-stream) of road.

STATION	NARRATIVE
15	Black Brook above asbestos site off of White Bridge Road.
16	Black Brook at New Vernon Road bridge. Sample taken up-steam of bridge.
16A	Black Brook at New Vernon Road bridge. Sample taken down-steam of bridge.
16C	North (down gradient) of New Vernon Road Asbestos Site at a red maple swamp just inside refuge boundary.
17	Great Brook at Woodland Road Trail crossing. Sample taken on up-stream side of bridge.
18	Great Brook up-stream of Asbestos Mounds A and B (near first oxbow east of mounds).
19	Un-named brook below junction of Pleasantville Road and Millbrook Road. Sample taken about 20 to 30 yards downstream of house (Willean) in first pool past house.
20	Middle Brook at Long Hill Road bridge. Sample taken up-stream from bridge just down-stream of Asbestos Mound A.
20A	Middle Brook at Long Hill Road bridge. Sample taken down-stream from bridge (Pool 1).
21	Un-named drainage at second bridge south of gas line easement on Long Hill Road. Sample taken down-stream of bridge and up-stream of Harding Dump. Fish for station 21 were collected in Great Brook (first bridge south of gas line easement) below Long Hill Road.
22	Great Brook, up-stream of Pool 1 outlet.
23	Middle Brook outlet from Pool 1 on north side of maintenance road.
24	Un-named brook at intersection with gas line easement (near north refuge boundary, west of Long Hill Road). Sample taken up-stream of gas line.
25	Middle Brook east of Pleasant Plains Road. Sample taken up-stream of water control structure.
27	Black Brook at White Bridge Road crossing. Sample taken down-stream of bridge.
28	Un-named tributary to Black Brook at Brown Farm House, north of White Bridge Road. Sample taken in pool area north of house and down-stream of pipe culvert.
30	Primrose Brook at end of maintenance road for Pool 2 (down-stream of gas line easement).

STATION	NARRATIVE
31	Down-gradient side of Pool 2. Sample taken north (up-stream) of water control structure at Great Brook.
32	Pool 3B. Sample taken within 100 feet north (up-gradient) of water control structure for pool.
34	Pool 3A. Sample taken north (up-stream) of water control structure.
35	Un-named ditch draining to Great Brook behind refuge manager's house. Sample taken down-stream of where a ditch from the north joins a ditch running west to east.
37	West side of Miele property. Sample taken in open water depression west of sandy borrow area and east of refuge border sign.
39	East side of Rolling Knoll Landfill on refuge property (east of 90 degree turn in boundary). Fish collected in flooded timber (off landfill) and sediment collected south of flooded timber on western side of pool vegetated by cattail (on landfill).
39A	Ditch forming eastern toe of Rolling Knoll Landfill along refuge boundary.
40	Seep south of southeast toe of Rolling Knoll Landfill.
41	West of Rolling Knoll Landfill's southwest tip along refuge boundary.